

Amendments to the Specification:

Please amend paragraph [0015] as follows:

[0015] Accordingly, in a first aspect, the invention provides an off-axis projection system for displaying an optical image on a display surface based on input image data.

The projection system comprises:

- (a) an image processing unit for receiving the input image data and generating distortion-compensated image data;
- (b) a projection light engine coupled to the image processing unit for receiving the distortion-compensated image data and projecting a distortion-compensated optical image that corresponds to the distortion-compensated image data; and,
- (c) an optical reflection assembly coupled to the projection light engine, the optical reflection assembly comprising at least one curved mirror, the at least one curved mirror including an aspherical rotationally non-symmetric mirror having a vertically oriented concave surface and a horizontally oriented surface with a varying degree of concave or convex curvature on an upper surface that smoothly transitions to a varying degree of convex curvature on a lower surface for reducing spatial distortion on the displayed optical image, the at least one curved mirror being positioned in the optical path of the distortion-compensated optical image emerging from a projection lens for producing a displayed optical image with reduced distortion on the display surface;

wherein, the image processing unit [performs distortion compensation on the digital values of] is adapted to distortion-compensate the optical image represented by the input image data such that when the distortion-compensated optical image is projected through the projection light engine and reflected off ~~[[from]]~~ the optical reflection assembly, the optical and geometric distortions associated with the projection light engine and the optical reflection assembly are substantially eliminated in the displayed optical image.

Please amend paragraph [0016] as follows:

[0016] The invention provides in another aspect, an off-axis projection method for displaying an optical image on a display surface of an off-axis projection system based on input image data. The method comprises the steps of:

- (a) receiving input image data [in digital format] and electronically generating distortion-compensated image data;
- (b) providing a distortion-compensated optical image that corresponds to the distortion-compensated digital image data; and,
- (c) reflecting the distortion-compensated optical image off an optical reflection assembly to produce ~~[[an]]~~ a displayed optical image for projection on the display surface, the assembly comprising at least one curved mirror, the at least one curved mirror being an aspherical rotationally non-symmetric mirror having a vertically oriented concave surface and a horizontally oriented surface with a varying degree of concave or convex curvature on an upper surface that smoothly transitions to a varying degree of convex curvature on a lower surface for reducing spatial distortion on the displayed optical image. ~~[[said]]~~ the at least one curved mirror being positioned in the optical path of the distortion-compensated optical image emerging from the projection lens to produce a displayed optical image with reduced distortion on the display surface;

wherein step (a) comprises [applying distortion compensation to the] distortion-compensating the optical image represented by input the image data such that when the distortion-compensated optical image is reflected off the optical reflection assembly, the optical and geometric distortions associated with the projection system are substantially eliminated in the displayed optical image.

Please amend paragraph **[0020]** as follows:

[0020] FIGS. 1C and **[FIG.]** 1D are distortion and focus plot diagrams that illustrate the distortion inherent in the direct projection system of FIG. 1B;

Please amend paragraph **[0057]** as follows:

[0057] FIG. 19D shows the prior art projection light engine of FIG. 19B used in a 30 degree off-axis projection system (note that the lens barrel is horizontal but the lens is still projecting an image upwards at 30 degrees);

Please amend paragraph **[0074]** as follows:

[0074] In an RP (rear-projection) off-axis system designed according to this invention, a Fresnel lens will be needed as well, but it must deal with an asymmetrical distribution of angles of incidence of light striking the display surface, because of the off-axis projection geometry. This forces the center of the Fresnel lens to be considerably offset downwards from the center of the display surface, the degree of offset being dependent on the DtoD ratio of the system (amount of off-axis geometry being used). Thus, Fresnel lenses that are used in off-axis projection systems are not symmetrical. These asymmetrical Fresnel lenses must be designed to collimate light from a much larger cone of projected light that includes, in particular, the off-axis light path being designed for. In fact, **[In]** in systems with a higher DtoD ratio, the projection axis is more inclined, requiring more keystone distortion to be corrected. This means that a wider cone of light emanates from the micro-display with a larger spread of incident light angles between the bottom and top of the display surface. The optical axis of this cone of light must pass through the center of the Fresnel lens, and the center of the Fresnel lens becomes offset downwards to a greater degree in order to satisfy this optical requirement. In a projection system with an extreme off-axis configuration, the optical center of the Fresnel lens might be off the screen entirely. Consequently, the diameter of the Fresnel lens will be much bigger than the screen diagonal, and a rectangular piece is cut out of it to be laminated with the screen. Obviously, if only one usable Fresnel lens segment can be extracted from the larger diameter structure, the cost of

the lens is higher. In some asymmetrical Fresnel lens designs, more than one usable lens segment may be cut out of the basic large diameter complete Fresnel lens, helping to amortize the cost of machining the molds that are used to make the Fresnel lenses.

Please amend paragraph [0080] as follows:

[0080] FIGS. 8A-8C illustrate the surface curvature of the corrector lens **49** of FIG. 6 that is used (along with shifting and tilting the micro-display device **24** relative to projection lens **25** or vice-versa) to decrease the de-focusing (i.e. beam spreading) of the light beam projected by projection lens **5** onto the aspherical mirror **39**. The corrector lens **49** is also an aspherically curved, non-rotationally symmetric lens that corresponds to the curvature of the aspherical mirror **39**, and is designed for use with the projector lens **5** that is being used in the projection system **10**. Specifically, the corrector lens **49** is designed to be positioned in front of the ~~[[projector]]~~ projection lens **5**, as shown in FIG. 6. FIG. 8A shows the curvature of the corrector lens **49** in the horizontal direction and FIG. ~~8B~~ ~~[[S]]~~ 8B shows the curvature of the corrector lens **49** in the vertical direction. FIG. 8C shows a perspective view of the curvature of the corrector lens **39** with the horizontal direction shown left to right, the vertical direction extending into the page (i.e. along the Y-axis) and the height (or thickness) of the curvature represented by the ~~[[z]]~~ Z-axis. The shape of the corrector lens **49** is similar to the shape of the aspherical mirror **39** and will also be rotationally non-symmetric and laterally symmetric about the vertical axis. In particular, the corrector lens **49** is a horizontally convex cylindrical lens that transitions from a smaller radius of curvature to a larger one and also has a vertical concave shape. However, the corrector lens **49** is flatter (i.e. has larger radii of curvature in both horizontal and vertical directions).

Please amend paragraph [0106] as follows:

[106] Referring now to Figure 14, shown therein is a projection system **400** ~~[[300]]~~ having a projection light engine **14**, a single curved mirror **402** and a display surface **20**. The single curved mirror **402** is approximately the same size as the display surface **20**. The projection system **400** ~~[[402]]~~ comprises the same components as the

projection system **10** (see FIG. 5). However, the optical reflection assembly comprises only the single curved mirror **402**. As before, a custom projection lens may be designed for this application to correct for the beam-spreading defocus of the single curved mirror **402**. As before, the off-axis projection, and the distortion correction performed by the combination of lens and mirror profile design and image processing, allows the cabinet thickness to be reduced. Because the defocusing can be better controlled with a large, curved mirror, more severe off-axis geometry can be used, resulting in increased improvements to DtoD ratio and cabinet thickness.

Please amend paragraph **[0108]** as follows:

[0108] Referring now to FIGS. 14B-14D, shown therein are distortion plots and focus spot diagrams for the projection system **400** of FIG. 14A. FIG. 14B shows the distortion correction performed by the large curved mirror, which is clearly quite good, almost making full use of all the available pixels. FIG. 14C shows the focus spot diagrams without a corrector lens element and FIG. 14D shows the focus spot diagram with a corrector lens element. In these results, the projection system **400** has a 60 inch diagonal display screen and a cabinet depth of 11 inches. The sag of the mirror **402** was 40 mm, or about 1.5 inches. If FIGS. 14B and 14D are compared with the conventional on-axis performance illustrated in FIGS. 1C and 1D, one can see that the large, curved mirror technique can yield image quality that almost does not require any image processing to correct for residual correction, using off-the-shelf lenses with correction. This also implies that by using a more advanced custom lens design[[s]] and using other techniques such as tilt, offset, and image processing, more gains in DtoD ratios and cabinet depth reductions may be realized. Electronic correction was not used for FIGS. 14B-D.

Please amend paragraph **[0128]** as follows:

[0128] Referring now to FIG. 20B, the projection light engine **900** with built-in micro-display tilt is shown in a configuration satisfying the Scheimpflug condition. The

"plane of best focus" shown in the figure is actually a plane of optimal focus, as the best focused points always lie along a spherical surface. This plane is shown intersecting the field of curvature of the projected image. The display surface must be moved to coincide with this plane by mechanically reducing the angle between the plane of the display surface and [[and]] a plane perpendicular to the principal axis of the projection lens. The other components of the projection system such as the aspherical mirror, etc. are not shown for clarity, but obviously, they are present. The best focus is always along an arc, so there will always be focus problems on a flat screen. In an off-axis projection system of the present invention, the projection light engine **900** with built-in tilt can be used to reduce the focus problems. If the display screen was tilted a few degrees to coincide with the plane of optimal focus (which is superimposed for best fit in the spherical wavefront of best focus) then spot sizes would be improved. Conceptually, it is easier to tilt the projection lens **902** backward relative to the micro-display **904** and then tilt the projection light engine forward a few degrees so that the Scheimpflug principle is met. Mechanically, this has to be implemented by careful design of the lens mount and the use of precisely inclined lens barrels and/or off-axis machining and/or special shims/washers, etc. The tilted projection lens **900** can be used in any of the projection systems of the present invention. The concept is also applicable to both front and rear projection systems.

Please amend paragraph **[0131]** as follows:

[0131] An example of a custom lens that can be used with an aspherically curved, rotationally asymmetric mirror is shown in FIGS. 21A-C. It is to be noted that this design was also used to work with an aspherically curved, rotationally symmetric mirror (in order to substitute this mirror with a Fresnel mirror) as well (see FIGS. 18F-G), but a surface profile of one of the lens elements had to be changed. Referring now to FIGS. 21A and 21B, shown therein are top and side cross-sectional views, respectively, of an eight-element custom projection lens **950**. The elements of the projection lens **950**, starting from the right are: a first element **952** with a convex and concave

surface,[[:]] a second element **954** with an asymmetrical, aspherical concave surface, a third element **956** which is a doublet, a fourth element **958** which is a biconvex lens, a fifth element **960** which is a doublet, a sixth element **962** which is a doublet, a seventh element **964** which is a biconvex lens, and an eighth element **966** which is a plano-convex lens element. Both lens shift and tilt are used and FIG. 21B shows the shift (offset) quite clearly, though the tilt is a little harder to see. The tilt begins at lens element **966**.

Please amend paragraph **[0142]** as follows:

[0142] Current state of the art for DtoD ratios in consumer RPTVs is about 3.2:1. Current state of the art for DtoD ratios in professional rear projection systems (which are 3 to 5 times more expensive than consumer products) is about 6:1. The various embodiments of this invention will allow consumer RPTVs to achieve DtoD ratios of over 5:1. For example, it is possible to achieve a DtoD ratio of 5.5:1 using a large curved mirror design with a simple aspherical projection lens and the image processing unit. Another example is a DtoD ratio of 7.5:1 by adding micro-display shift and tilt to the previous case and re-optimizing the lens profile for a custom design. Other examples for consumer RPTV products include: a) a DtoD ratio of 6 for a small curved mirror, off-axis projection system (similar to that shown in FIG. 6), using no tilt or shift in the projection lens, with an external corrector lens; b) a DtoD ratio of 7 for a large curved mirror, off-axis projection system (similar to that shown in FIG. 16A), using no tilt or shift in the projection lens, with an external corrector lens; c) a DtoD ratio of 7.5 for a large curved mirror, off-axis projection system using tilt as well as shift in a custom projection lens design; (this could be achieved by using the lens shown in FIGS. 18F-G in the configuration shown in FIG. 18A) and, d) a DtoD ratio of 8.5 for a large Fresnel mirror, off-axis projection system using tilt as well as shift in a custom projection lens design (this could be achieved by using the lens shown in FIGS. 21A-B in the configuration shown in FIG. 16A). It should be understood that the details about screen diagonal and cabinet thickness are not very important, only the ratios, as everything scales linearly as

long as certain minimum mechanical dimensions are met in order for the projection light engine to fit within the thickness of the cabinet.

Please amend paragraph **[0149]** as follows:

[0149] It should be noted that the various embodiments shown herein [[area]] are also applicable to a compact front projection system. However, for a front projection system, there is no need for a Fresnel lens in the display screen.